Frequency of Low-Level, Single-Layered Clouds

Assessing Partly Cloudy Pixel Retrievals

February and March 1998, Low-level, Single-layered Clouds, 50-km Scale

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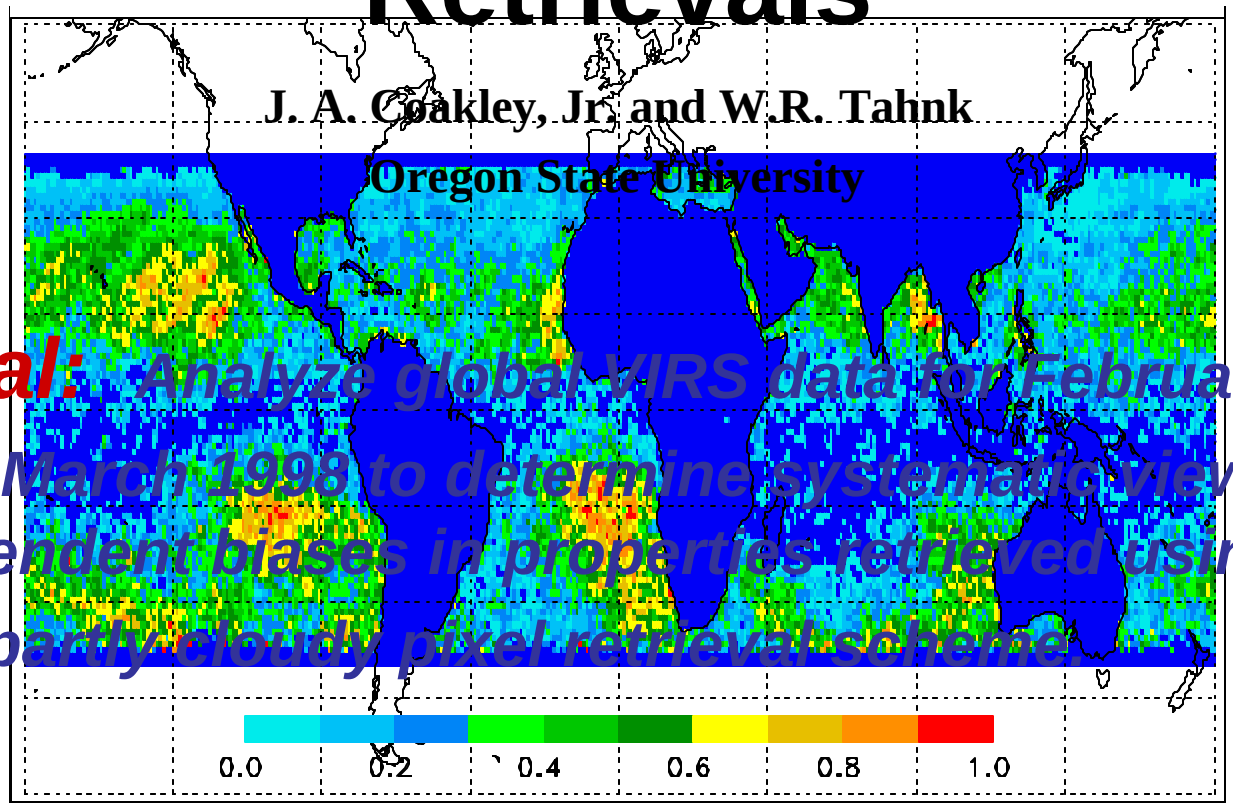


Goal: *Analyze global AVHRR data for February and March 1998 to determine systematic view-dependent biases in properties retrieved using the partly cloudy pixel retrieval scheme.*

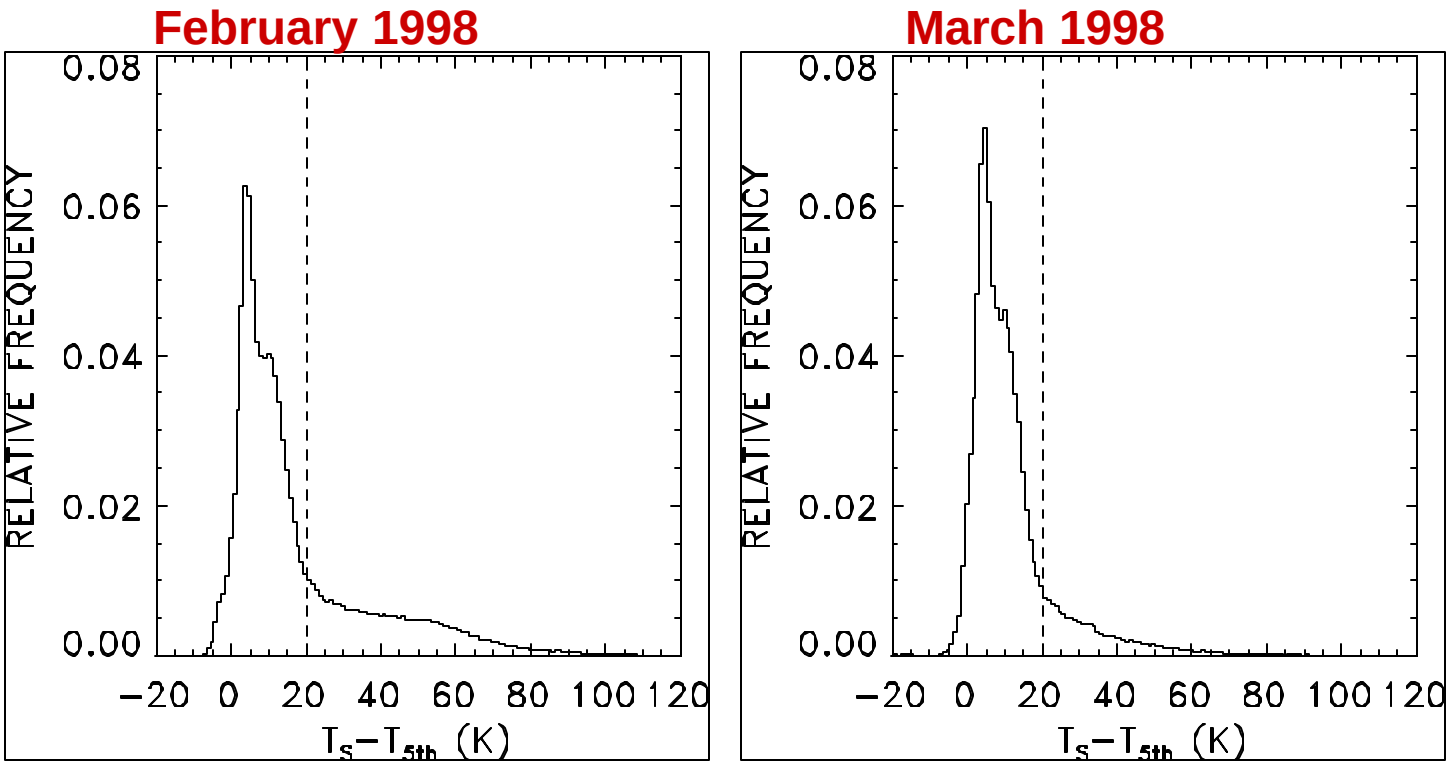
Analysis Constraints

- Ocean only.
- No sun glint.

  Reflection angle greater than 30° from the angle for specular reflection.
- Region contains estimate of cloud-free radiances from climatology for February and March.

Identification of Regions with Low-Level Clouds

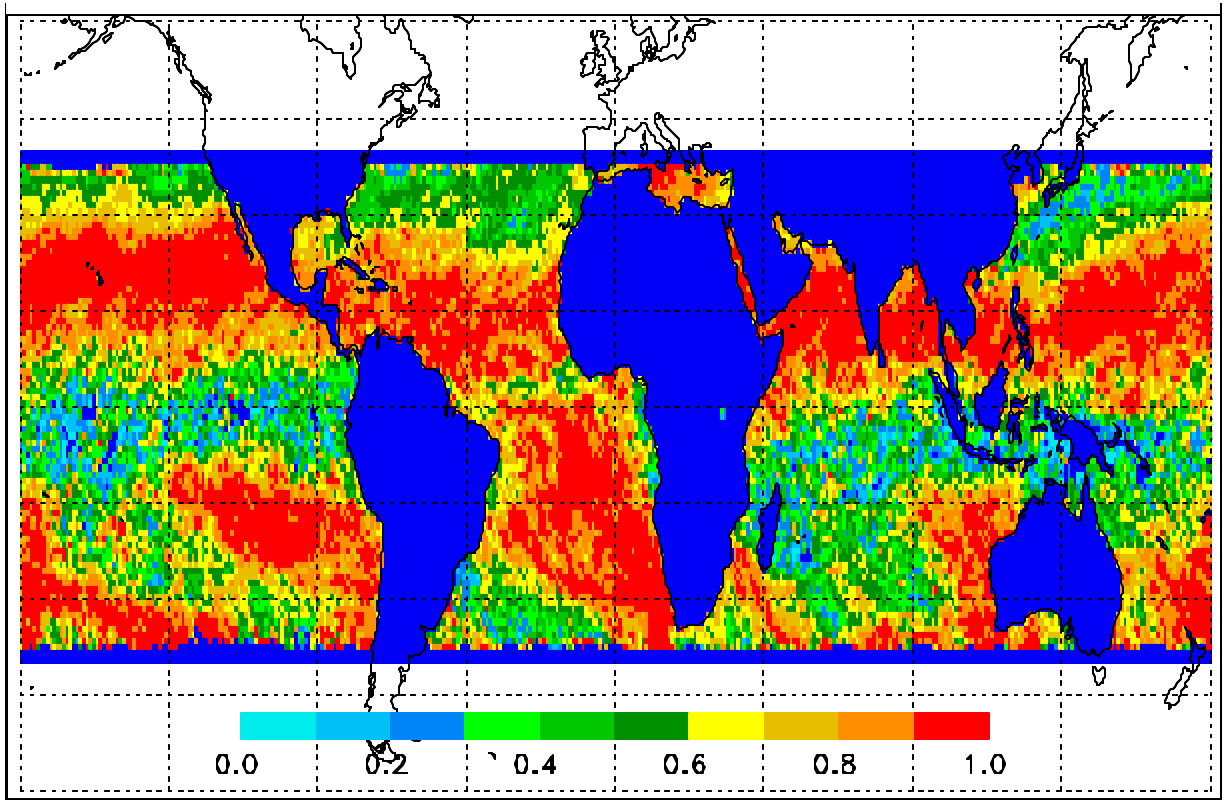
Surface Temperature and 5th Percentile of 11-μm Brightness Temperature, 50-km Scale



$T_S - T_{5\text{th}} > 20\,\text{K}$ ***indicates no upper-level clouds present.***

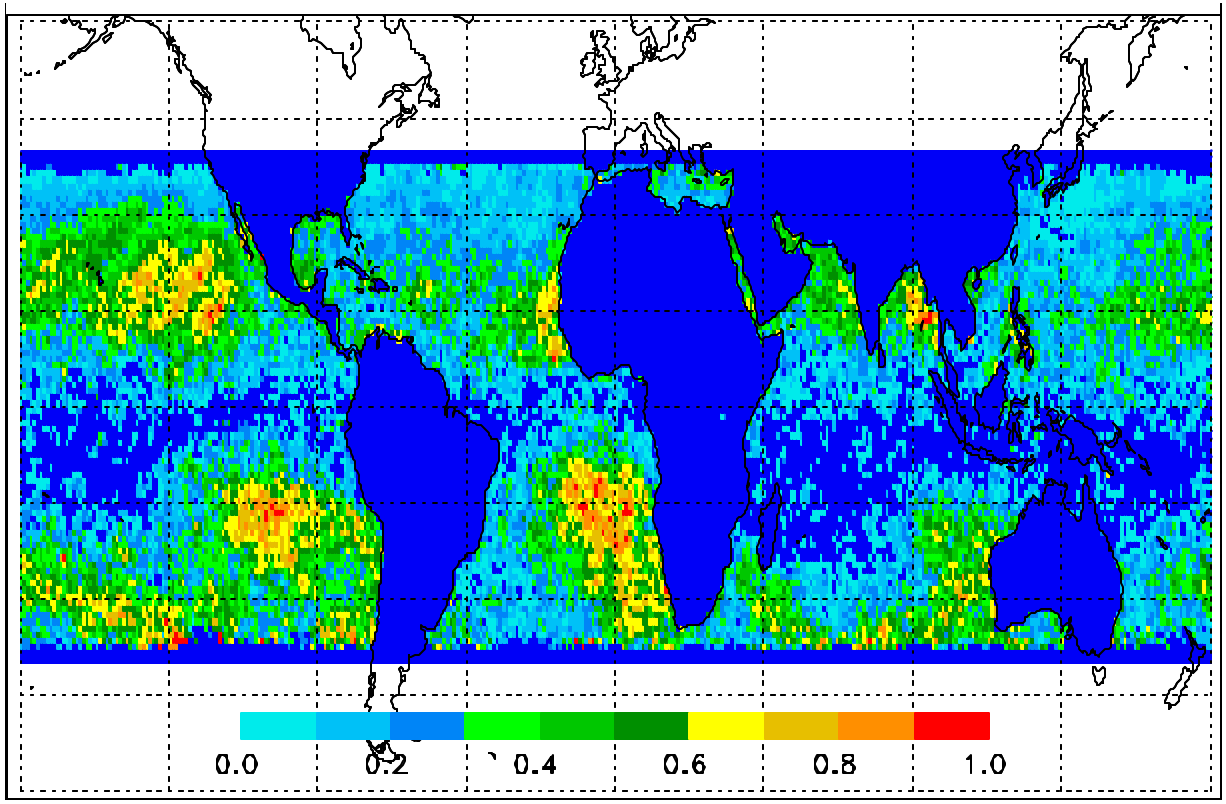
Frequency of Low-Level Clouds

February and March 1998 50-km Scale



Frequency of Low-Level, Single-Layered Clouds

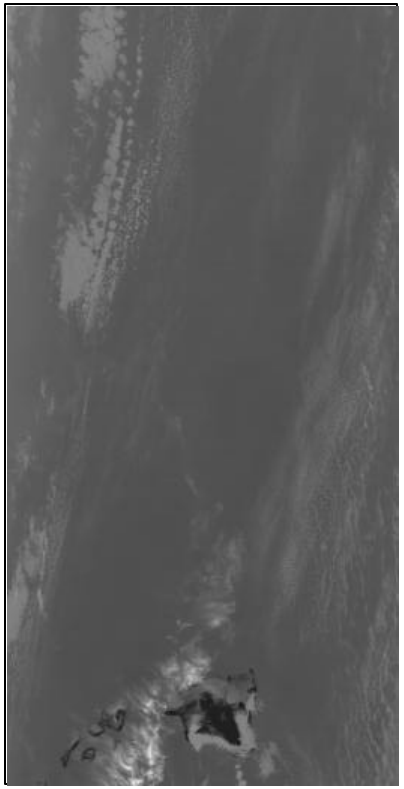
February and March 1998, Low-level, Single-layered Clouds, 50-km Scale



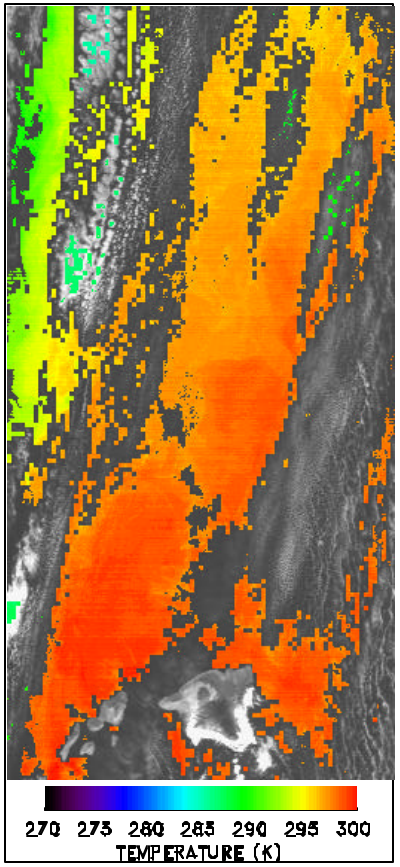
Low-level Cloud Systems Lacking Overcast Pixels

0.84-mm

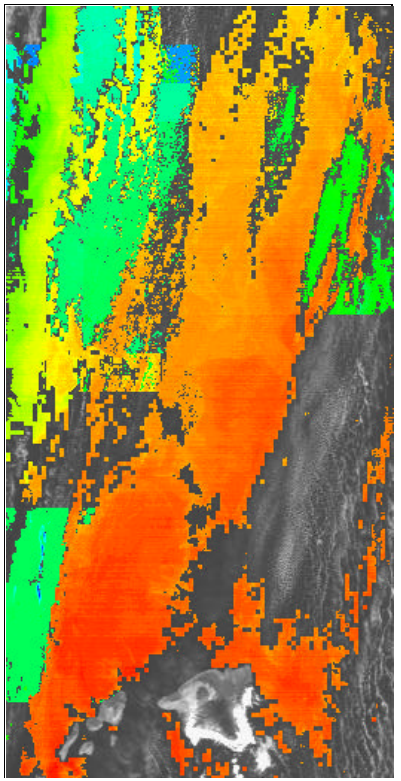
11-mm



Identified Overcast and Cloud-free

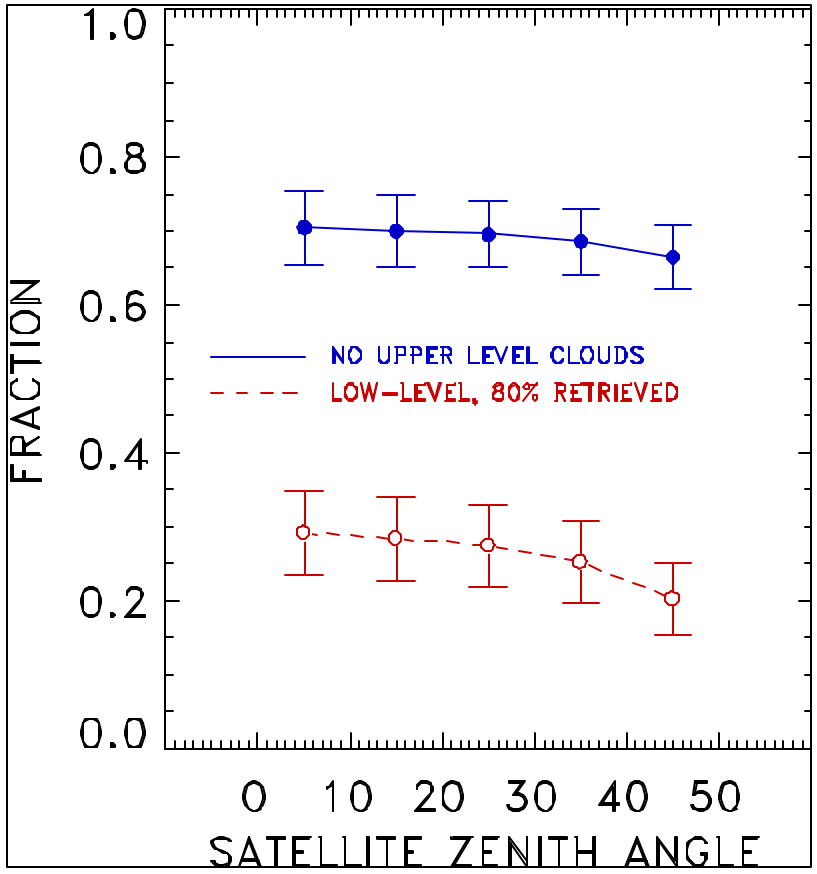


Partly Cloudy Pixel Retrievals



Occurrences: Low-level cloud Systems and Low-level cloud Systems with Retrievals

February and March 1998, Low-level, 50-km Scale



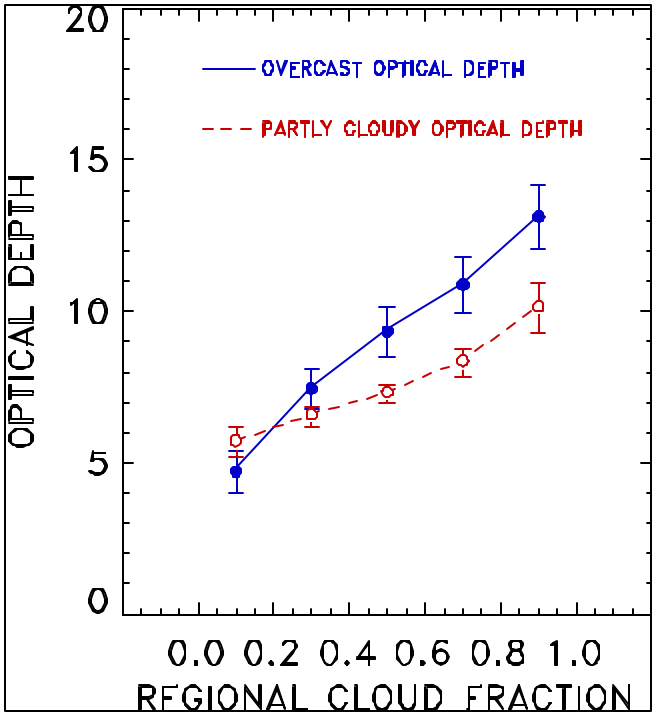
- **No upper-level clouds:**

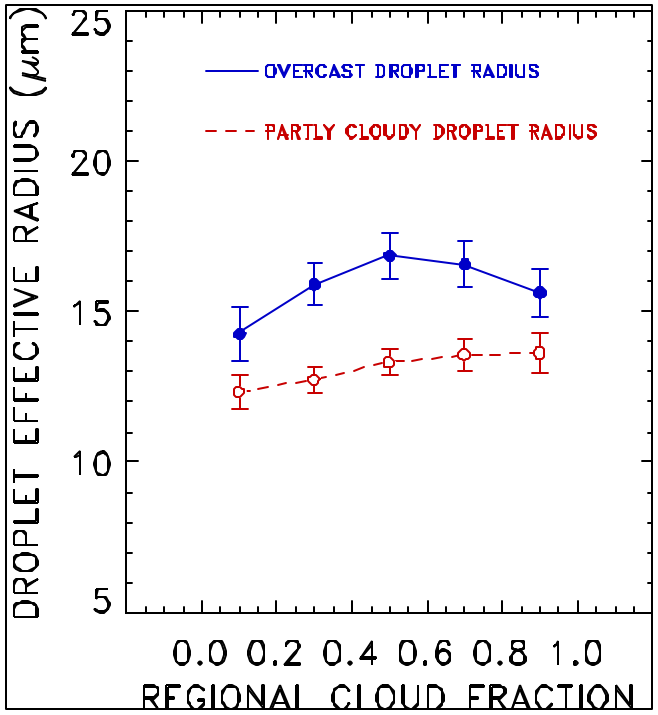
$$T_S - T_{5\text{th}} < 20\,\text{K}$$

- **50-km scale regions deemed to have successful retrievals if more than 80% of pixels yielded retrievals.**
- **Detection of upper-level clouds increases at the limb, and frequency of cloud-free observations decreases at limb.**
- **Owing to procedures used to analyze layer altitudes, frequency of successful retrievals decreases at the limb.**

Optical Depth, Droplet Effective Radius, and Cloud Fraction

February and March 1998, Low-level, Single-layered Clouds, 50-km Scale

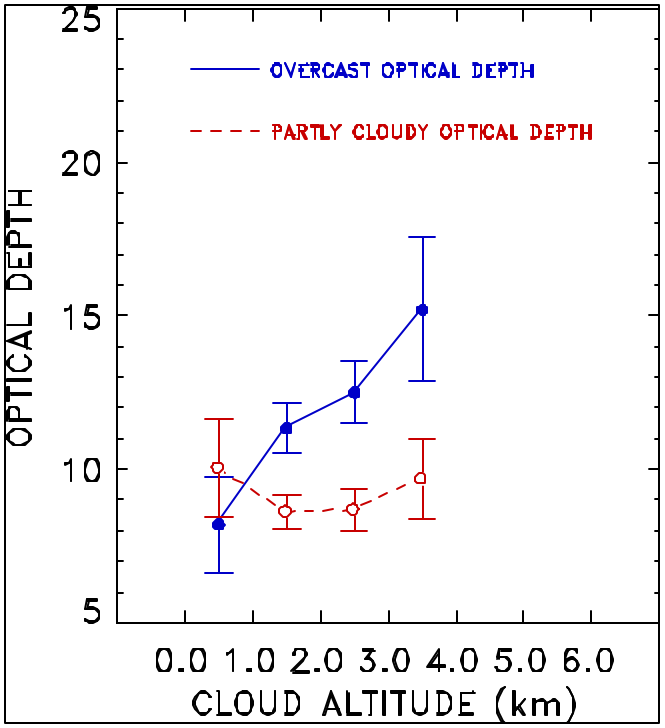


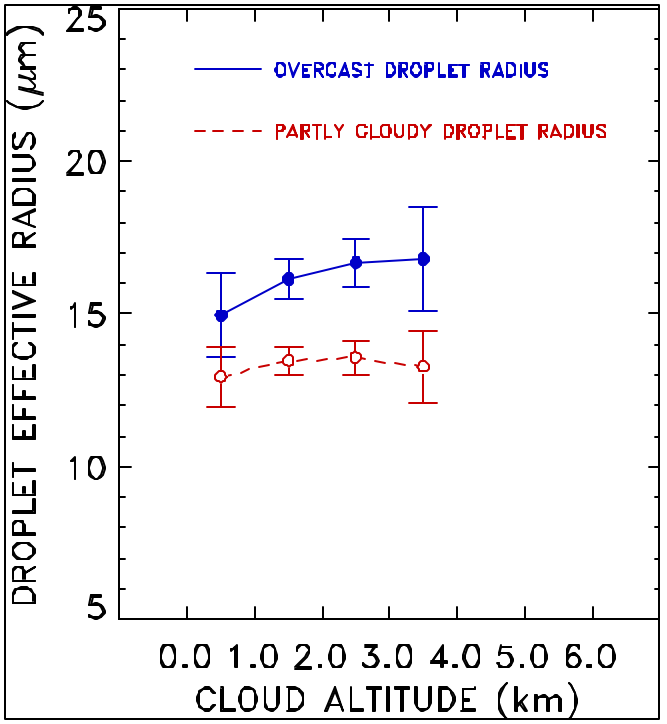


- ***Cloud optical depth and droplet radius smaller for clouds in partly cloudy pixels.***
- ***Optical depth increases with increasing regional cloud cover.***

Optical Depth, Droplet Radius, and Cloud Altitude

February and March 1998, Low-level, Single-layered Clouds, 50-km Scale

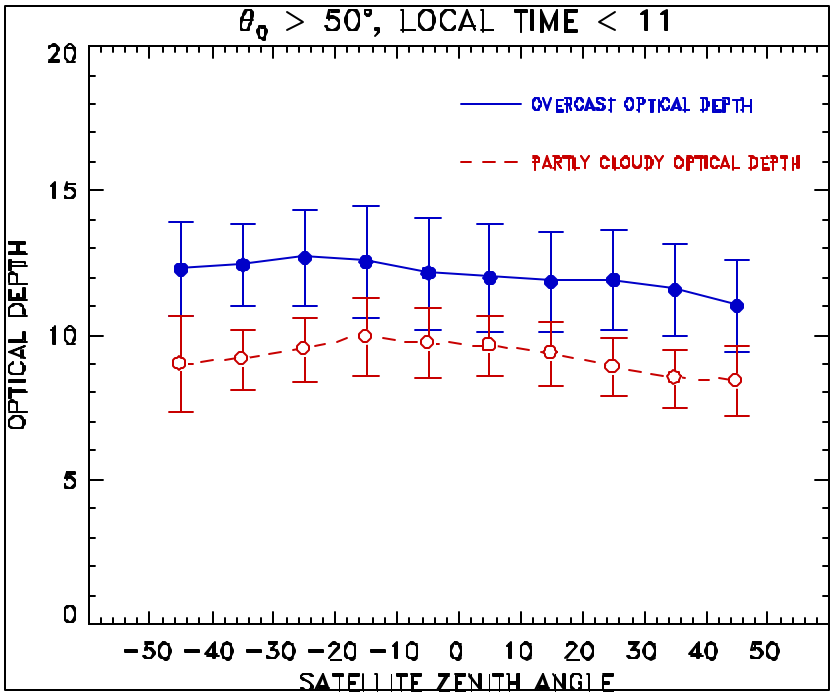




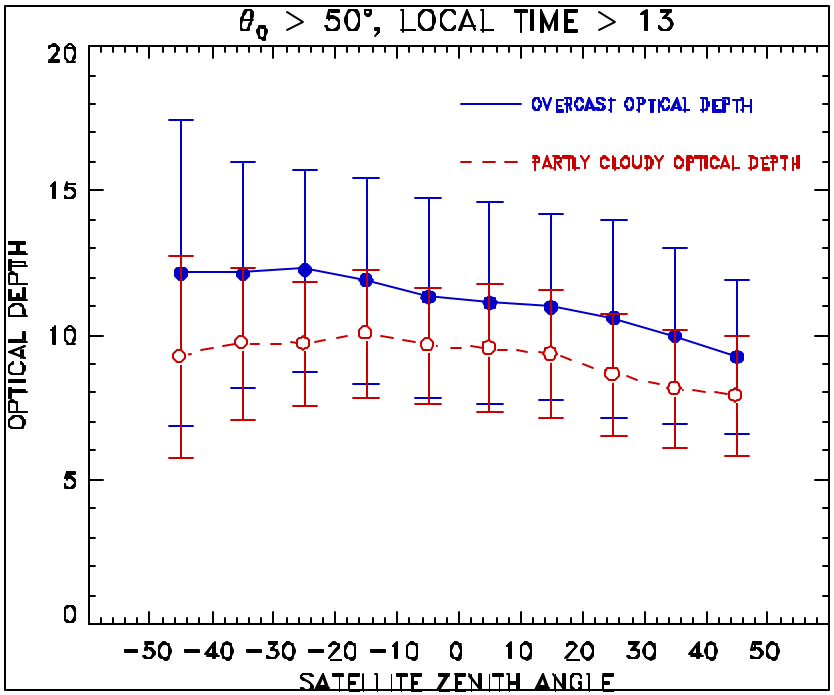
- ***For clouds in overcast pixels, optical depth and droplet radius increase with increasing altitude.***

Retrieved Optical Depth and Viewing Geometry for Low Sun

Morning



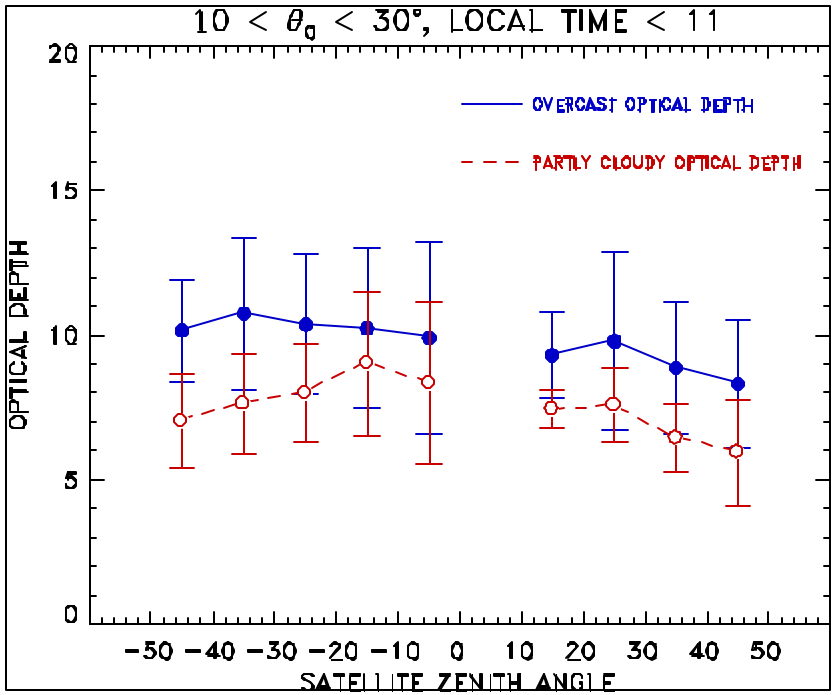
Afternoon



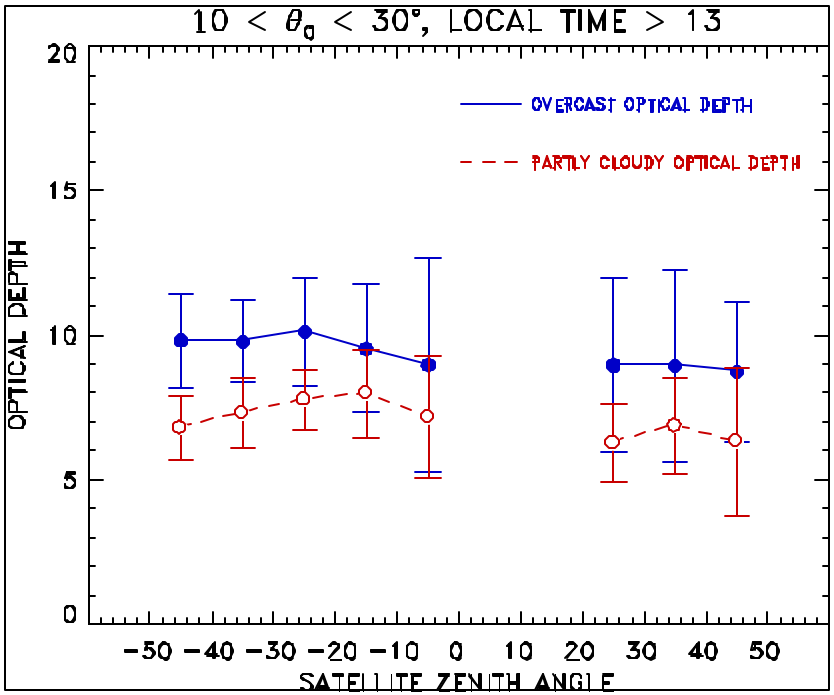
Bumps, "Norman's Bumps" on the top of layered clouds lead to smaller retrieved optical depths in the direction of forward scattering.

Retrieved Optical Depth and Viewing Geometry for High Sun

Morning



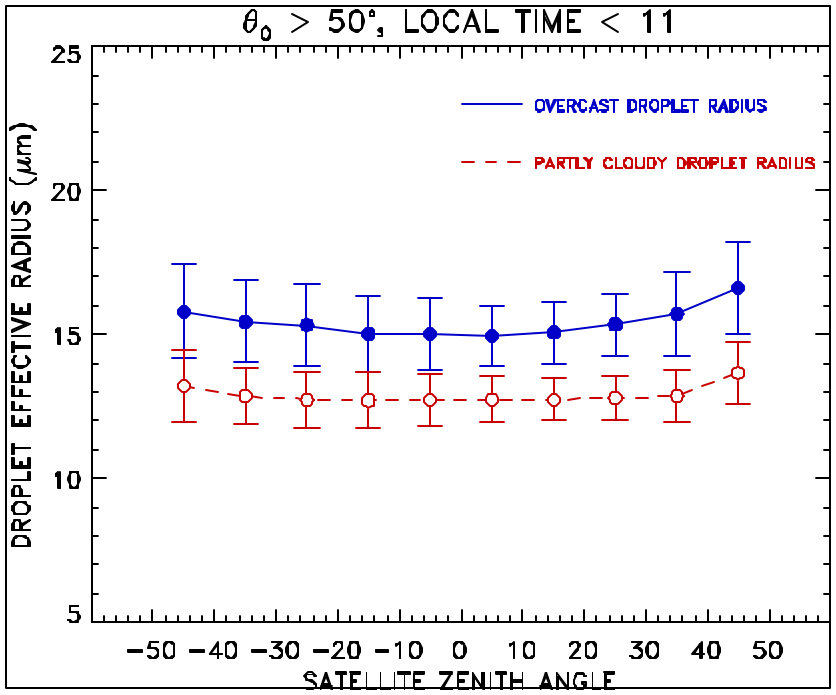
Afternoon



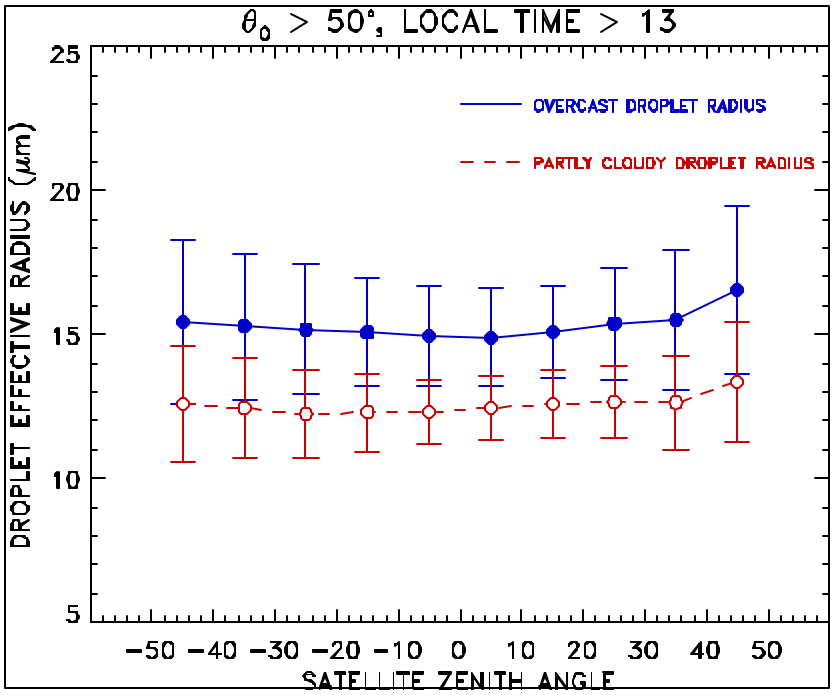
Bumps, less effective when sun is high. Optical depths are smaller when sun is high, but the comparison is between clouds at midlatitudes and clouds in the tropics.

Retrieved Droplet Effective Radius and Viewing Geometry for Low Sun

Morning



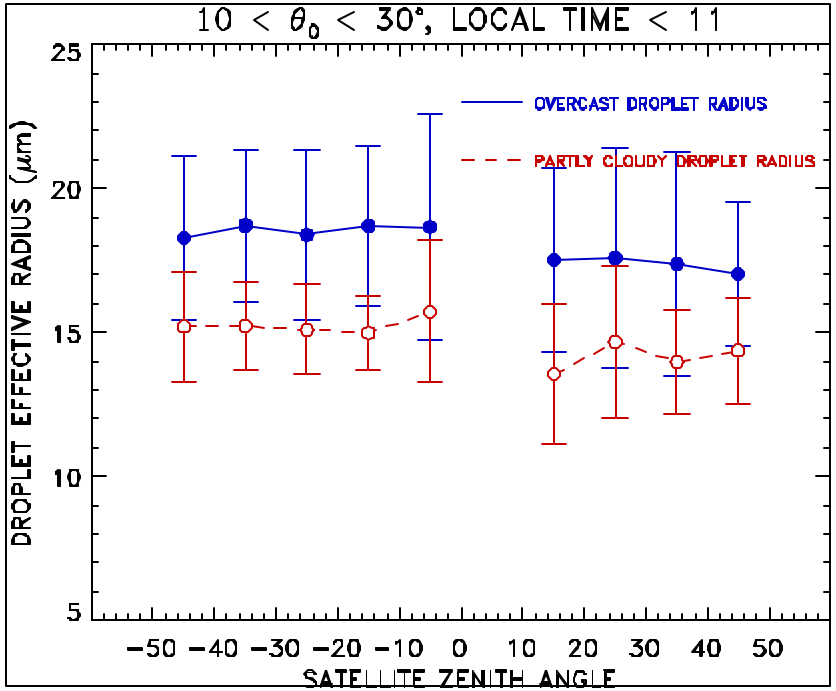
Afternoon



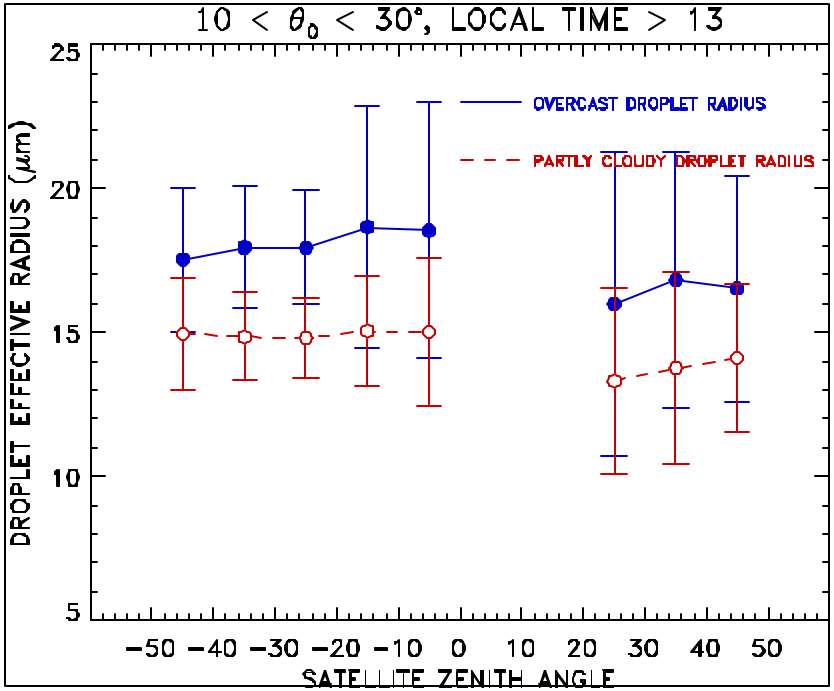
Bumps lead to larger retrieved droplet effective radii in direction of forward scattering. The increase in droplet radius for the backscattered direction is also suggested by 3-D radiative transfer calculations.

Retrieved Droplet Effective Radius and Viewing Geometry for High Sun

Morning



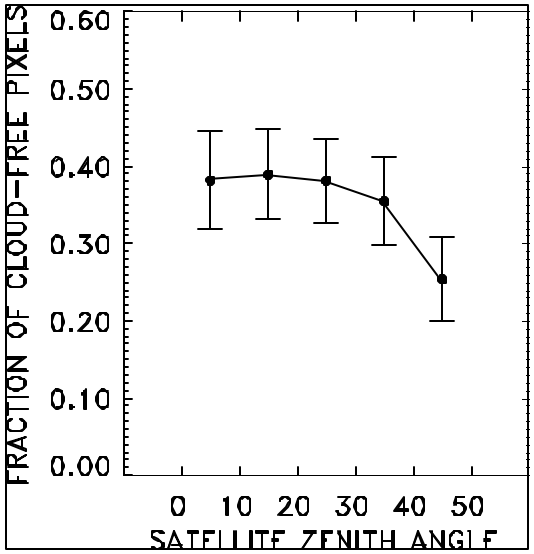
Afternoon

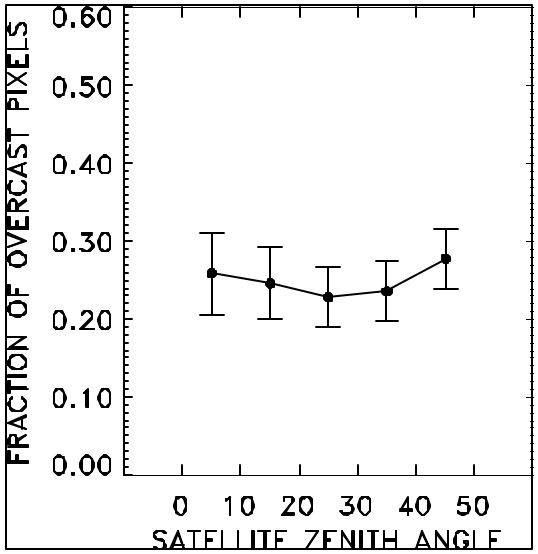


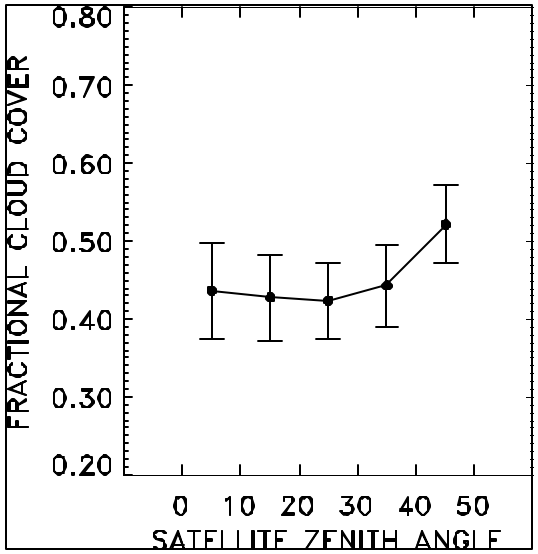
Retrieved droplet effective radius larger when sun is high. In other words, clouds appear to be "less reflective" for high sun. But, the comparison is between clouds at midlatitudes and clouds in the tropics.

Fractions of Cloud-free and Overcast Pixels

February and March 1998, Low-level, Single-layered Clouds, 50-km Scale







- ***Frequencies of cloud-free pixels decrease and overcast pixels increase with satellite view zenith angle.***
- ***Cloud cover fraction is relatively constant to 35° but then increases with increasing satellite zenith angle.***

Summary

Retrieved Properties for Single-layered, Low-level Maritime Clouds

- **Optical depths and droplet radii increase as cloud altitudes increase.**
- **Optical depths increase as regional cloud cover increases.**
- **Droplet radii also increase as regional cloud cover increases, but radii remain relatively constant once regional cloud fraction > 0.1.**
- **Clouds in partly cloudy pixels have smaller optical depths and droplet radii than nearby clouds in pixels that are overcast.**
- **The retrievals exhibit the plane-parallel biases noted previously (Loeb and Davies, 1996 & 1997; Loeb and Coakley, 1998)**
  - **a) Optical depths decrease and droplet radius increases with increasing satellite zenith angle in the direction of forward scattering.**
  - **b) Optical depths increase and droplet radii appear to increase with increasing solar zenith angles, but the interpretation may be compromised by geographic and diurnal differences in cloud properties.**